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Appendix A: Synthesis of Studies in the Fall Low Salinity Zone of the San Francisco Estuary, September-December 2011

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Appendix A

Section A.1: Dayflow

Dayflow was the source for basic flow data used in this report. Full documentation and data for Dayflow can be obtained at this website: *http://www.water.ca.gov/dayflow/*. The following description is directly from the website.

> Dayflow is a computer program designed to estimate daily average Delta outflow. The program uses daily river inflows, water exports, rainfall, and estimates of Delta agriculture depletions to estimate the "net" flow at the confluence of the Sacramento and San Joaquin Rivers, nominally at Chipps Island. It is a key index of the physical, chemical, biological state of the northern reach of the San Francisco Estuary.
>
> The Dayflow program also estimates these flow and parameter estimates as daily averages:

1. Net flow through the Delta Cross Channel and Georgiana Slough (when measured flow is not available).
2. Net flow at Jersey Point (also called QWEST)
3. Position of X2, the 2 ppt salinity isohaline.

The Dayflow estimate of Delta outflow is referred to as the "net Delta outflow index" (NDOI) because it does not a account for tidal flows, the fortnight lunar fill-drain cycle of the estuary, or barometric pressure changes. It is a quantity that never actually occurs in real time. Rather it is an estimate of the net difference between ebbing and flooding tidal flows at Chipps Island (~ + / - 150,000 cfs), aliased to a daily average. Depending on conditions, the actual net Delta outflow for a given day can be much higher or lower than the Dayflow estimate. An example comparison of Dayflow output with measured daily average outflow can be seen can be seen here.

Dayflow is computed once per year following the water year (October 1). At that time, we request official QA/QC'd data from several (Table A1) sources. Once all input data is received , we compute the Dayflow estimate of Delta outflow. Our annual goal is to provide data for the previous water year by January 1.

Table A1. Responsible agencies and input data used as input to the Dayflow program.

Responsible Agency	Input data
USGS	Sacramento River at Freeport, Yolo Bypass at Woodland, Cosumnes River at Michigan Bar, San Joaquin River at Vernalis, Delta Cross Channel, Georgiana Slough
USACOE	Calaveras River
EBMUD	Mokelumne River at Woodbridge
DWR O&M	Precipitation at Stockton Fire Department, Clifton Court Forebay gate flow, Barker Slough export, Byron Bethany ID depletion, X2 (only when outflow is negative)
DWR Bay-Delta	Estimated Delta island consumptive use
DWR DPLA	Sacramento Weir spill, Lisbon Weir flow
USBR	Delta Cross-Channel gate status, Tracy export, Contra Costa export
SCWD	Lake Barryessa releases, Lake Solano inflow, Putah Creek

Over time, some inflow inputs have been lost because stream flow gages have been abandoned or discontinued due to lack of funding. The input data is further described in the Dayflow program documentation.

In 2000, the software used to perform Dayflow calculations was rewritten in Java. Input data is stored in a HEC-DSS file, and output is written to ASCII, excel, and DSS format files. Data are available in multi or single years.

The stations used in Dayflow calaulations are shown in Figure A1. We utilized three outputs from Dayflow. We utilize the net Delta outflow index; however for simplicity we refer to it as average daily net Delta outflow. Note that this is a calculated rather than a measured value. We use daily X2. Dayflow uses the following autoregressive lag model to calculate X2:

$$X2(t) = 10.16 + 0.945 * X2(t-1) - 1.487\log(QOUT(t))$$

Where t = current day, and t-1 = previous day

We also use QWEST, the calculated net flow at Jersey Point in the San Joaquin River, as a measure of the influence of San Joaquin River outflow on total outflow. Note that QWEST is the quantity WEST in Dayflow data output files.

Figure A1. Sites used in Dayflow calculations from Dayflow (*http://www.water.ca.gov/dayflow/*).

Section A.2: Surface area and maps of LSZ

Our calculations of area were based on conversions of X2 to area from modeling runs for 1 April 1994 to 1 October 1995. The following methods are from a report provided through the courtesy of

Michael MacWilliams, Delta Modeling Associates. The results of the described modeling were used to produce the maps of the salinity gradient shown in Figures 15-17. The results were also used to create a look-up table (Table A1) for conversion of X2 to surface area of the LSZ. Dr. MacWilliams cautions us that the distribution of salinity in the estuary for the same X2 can differ depending on whether X2 is moving seaward or landward and the exact flow conditions in the year of interest. Therefore both the maps and surface areas should be considered estimates rather than exact values.

Table A2. Estimates of the area of the low salinity zone (LSZ) for specified X2.

X2 (km)	Area of LSZ (hectares)
30	18324
31	10933
32	9544
33	12675
34	15432
35	11423
36	7413
37	14905
38	20693
39	14154
40	17138
41	19969
42	19421
43	19131
44	21651
45	19746
46	18021
47	18525
48	18450
49	17743
50	17590
51	11525
52	8908
53	13429
54	7313
55	8576
56	4284
57	3530

58	4244
59	5127
60	4813
61	4498
62	5773
63	7007
64	6981
65	6999
66	7912
67	8467
68	8474
69	8743
70	8500
71	8632
72	8539
73	8585
74	8408
75	8231
76	8380
77	8162
78	7959
79	7369
80	6653
81	5313
82	5051
83	5075
84	4753
85	4483
86	4492
87	4456
88	4463
89	4604
90	4635
91	4653
92	4655
93	4953
94	5000
95	5025
96	4996

Figure references have been updated in the following text from Dr. MacWilliams.

Low Salinity Zone Area and Depth Analysis

January 23, 2012

Michael L. MacWilliams, Ph.D.

1. Introduction

This document presents an analysis of the Low Salinity Zone (LSZ) area and depth based on a simulation of historic conditions over an eighteen month period spanning from April 1, 1994 to October 1, 1995. Model validation of predicted salinity for this period will be document in an upcoming paper in collaboration with Wim Kimmerer and Ed Gross.

In this analysis, the LSZ is defined as the area with a salinity range between 1.0 psu and 6.0 psu (similar analyses have used a slightly wider salinity range from 0.5 psu to 1.0 psu). This analysis focuses specifically on the relationship between X2 and the areal extent and average depth of the LSZ.

2. LSZ Habitat Area and Depth Calculation Approach

In this analysis, the LSZ habitat area is calculated using the predicted depth-averaged daily-averaged salinity for the simulation of a historic period spanning from April 1, 1994 to October 1, 1995. For each model time step (90 seconds), the depth-averaged salinity is calculated within each grid cell in the model domain, and then the daily-averaged depth-averaged salinity is calculated from the depth-averaged salinity calculated at each of 960 model time steps in each day. The daily-averaged LSZ habitat area for each day is then calculated by summing up the total area of the grid cells with depth-averaged daily-averaged salinity of between 1.0 psu and 6 psu within a specified geographic range. For this analysis, the geographic range extends from San Pablo Bay through the western and central Delta, and covers the domain shown in Figures 3-5. Area within the salinity range of the LSZ that is not within the domain of the maps shown on Figure 3-5 was not counted as LSZ habitat in this analysis.

Once the area of the LSZ is defined on a given day, the average depth of the LSZ for that day is calculated based on the daily-averaged water level within each cell which is within the LSZ. Water levels are only averaged during periods of when the cells are wet, such that the average depth of subtidal cells is calculated based on the average depth during the time period that cell was wet during each day.

2. X2 Calculation Approach

By definition X2 is the distance in kilometers from the Golden Gate to the tidally-averaged near-bed 2-psu isohaline. The 1995 Bay-Delta agreement established standards for salinity in the estuary. Specifically, the standards determine the degree to which salinity is allowed to penetrate up-estuary, with salinity to be controlled through Delta outflow (IEP, 2009). This regulation is based on observations that the abundance or survival of several estuarine biological populations in the San Francisco Estuary is positively related to freshwater flow (Jassby et al. 1995), although recent studies suggest that some of these relationships have changed (Sommer et al. 2007).

Jassby et al. (1995) provide a graphical depiction of X2 (Figure 2), showing X2 measured from the Golden Gate. The inset figure shows an X2 of about 75 km at Chipps Island and 81 km at Collinsville. In the UnTRIM Bay-Delta model, X2 is calculated along the axis of the estuary along the transects shown in Figure A2. For X2 greater than 75 km, the distance from the Golden Gate to the location of 2 psu bottom salinity is measured along both the Sacramento and San Joaquin transects, and the reported predicted reported “average X2” is the average of the Sacramento and San Joaquin X2 distances. Use of an average over a number of years, perhaps within water year types, could perhaps provide a consistent basis for conversion or modeling future areas.

Figure A2. Transects along the axis of northern San Francisco Bay used to measure X2 in the UnTRIM Bay-Delta model.

Section A3: Delta smelt habitat index

We used a look-up table (Table A3) to convert daily X2 to daily estimates of the delta smelt habitat index. The derivation of the habitat index is described in detail in Feyrer and others (2010). In essence, the habitat index weights the probability of occurrence of delta smelt at a FMWT station by a surface area associated with that station. The probability of occurrence of delta smelt at a station is based on a general additive model incorporating water temperature, salinity, and turbity measured at the time fish were sampled. The habitat index was calculated as the average habitat index across the four months of the FMWT, September-October. The annual habitat index was then related to mean X2 from September to December using locally weighted-regression scatterplot smoothing (LOESS regression). The LOESS regression model was then used to generate a predicted habitat index value for each value of X2 in the look-up table.

Table A3. Delta smelt habitat index values for specified X2.

X2 (km)	Predicted Habitat Index
61	7343
62	7551
63	7724
64	7863
65	7967
66	8036
67	8069
68	8067
69	8027
70	7950
71	7837
72	7685
73	7491
74	7261
75	7000
76	6716
77	6414
78	6099
79	5735

80	5292
81	4835
82	4430
83	4081
84	3777
85	3523
86	3314
87	3160
88	3054
89	2996
90	2987
91	3028
92	3116
93	3252

Section A4: Fall midwater trawl

A description of the fall midwater trawl (FMWT) sampling program and data for fish abundance indices are available at: *http://www.dfg.ca.gov/delta/projects.asp?ProjectID=FMWT*. The FMWT is conducted by the California Department of Fish and Game under the umbrella of IEP monitoring activities. For convenience we reprint the general description of the FWMT sampling and then provide additional detail. We also include a map of the sampling locations (Figure A3).

Figure A3. Locations of fall midwater trawl sampling stations.

The Fall Midwater Trawl Survey (FMWT) has sampled annually since it's inception in 1967, with the exceptions of 1974 and 1979, when sampling was not conducted. The FMWT was initiated to determine the relative abundance and distribution of age-0 striped bass (*Morone saxatilis*) in the estuary, but the data has also been used for other upper estuary pelagic species, including delta smelt (*Hypomesus transpacificus*), longfin smelt (*Spirinchus thaleichthys*), American shad (*Alosa sapidissima*), splittail

(*Pogonichthys macrolepidotus*), and threadfin shad (*Dorosoma petenense*). The FMWT samples 122 stations each month from September to December and a subset of these data is used to calculate an annual abundance index. These 122 stations range from San Pablo Bay upstream to Stockton on the San Joaquin River, Hood on the Sacramento River, and the Sacramento Deep Water Ship Channel. Sampling takes approximately 9 days per month to complete. Historically, FMWT sampling occasionally began as early as July (1972) or August (1968-1973, 1993-1994, 1996-1997) and sometimes continued past December to March (1968-1973, 1978, 1991-2001) or beyond (1992-1995). The consistent January-March midwater trawl sampling conducted from 1991-2001 to track movements of mature adult delta smelt was replaced in 2002 with the more effective Spring Kodiak Trawl.

The midwater trawl net has mouth dimensions of 12 ft x 12 ft when stretched taught, but mouth dimensions will be smaller when under tension during a tow. Net mesh sizes graduate in nine sections from 8-inch stretch-mesh at the mouth to 0.5-inch stretch-mesh at the cod-end. All four corners of the net mouth are connected to planing doors, which together counteract the drag on net material and hold the net mouth open when being towed through the water. At each station a 12 minute tow is conducted during which the net is retrieved obliquely through the water column from bottom to surface. All fish, shrimp, and jellyfish are identified and enumerated. In addition, the crew measures water temperature, electrical conductivity (specific conductance), Secchi depth, and turbidity.

FMWT equipment and methods have remained consistent since the survey's inception, which allows annual abundance indices to be compared across time. Monthly and annual abundance indices are calculated using catch data from 100 "index" stations grouped into 17 regional "areas". Monthly indices are calculated by averaging catch per tow for index stations in each regional area, multiplying these means by their respective weighting factors (i.e., a scalar based on water volume) for each area and summing these products for all 17 areas. Annual abundance indices are the sum of the 4 (September-December) monthly indices

The FMWT is mandated by the Delta Smelt Biological Opinion for the coordinated operation of the Central Valley Project and the State Water Project.

We primarily use water quality data collected during sampling, specifically water temperature, electrical conductivity (converted to salinity), Secchi depth, and turbidity. Turbidity has only been measured since 2010. Estimates of *Microcystis* abundance have been made since 2008, using a visual ranking system (Figure A5). Ratings of 4 or 5 were never observed. We analyzed these data as occurrence data. Diet data were collected from delta smelt collected and preserved during the fall midwater trawl. Stomachs were dissected and inspected and prey items identified to the lowest practical taxon. Data are recorded as number of each prey taxon and weight of each taxon in the diet. We present data on weight of prey items in the diet. Center of distribution of the delta smelt population was determined by weighting the distance (km) of each station from the Golden Gate by the number of fish captured at that station. The data were then plotted with the median of the data considered to be the center of distribution of the population.

In 2011, water samples were collected from a second boat during the FMWT for the first time. These water samples were analyzed at the University of California Davis, under the direction of Dr. Randy Dahlgren. Samples were returned from the field on ice in the evening and processing began the next morning.

Algal pigments were determined using SM10200-H (Clesceri et al., 1998). Samples were filtered using a Whatman GF/F glass fiber filter within 12 h of delivery and the filters were frozen prior to extraction. The method was altered by using 90% ethanol for extraction instead of 90% acetone, and the glass fiber filters were freeze dried but not ground (Sartory and Grobselaar, 1984). Samples were analyzed by fluorometric determination with the limit of detection dependent on the volume of water filtered (200 to 1000 mL); generally about 0.5 µg L-1.

A subsample was filtered through a pre-rinsed 0.45 µm polycarbonate membrane (Millipore) for quantification of ammonium (NH4-N). NH4-N was determined spectroscopically with the Berthelot reaction, using a salicylate analog of indophenol blue (LOD ~ 0.010 mg L−1; Forster 1995). Analysis of NH4-N was completed within 48 hr of sample collection. The vanadium chloride method was used to spectroscopically determine NO3+NO2-–N (LOD = 0.01 mg L-1).

Laboratory quality assurance/quality control included implementation of Surface Water Ambient Monitoring Program (SWAMP) compatible standard laboratory procedures including replicates, spikes, reference materials, setting of control limits, criteria for rejection, and data validation methods (Puckett, 2002).

All data used in this report will be posted to an accessible website/ftp site once analyses are finalized in response to review panel comments.

References:

Clesceri, L.S., A.E. Greenberg, and A.D. Eaton (eds.). 1998. Standard methods for the examination of water and wastewater, 20th ed. American Public Health Assoc., American Water Works Assoc., and Water Environment Assoc., Washington, DC.

Doane, T. A.; Howarth, R. W. Spectrophotometric determination of nitrate with a single reagent. Anal

Lett 2003, 36, (2713-2722).

Forster, J.C. 1995 Soil Nitrogen, p. 79-87. In Alef, K., and P. Nannipieri (eds). Methods in Applied Soil Microbiology and Biochemistry. Academic Press.

Puckett, M. 2002. Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program ("SWAMP"). California Department of Fish and Game, Monterey, CA. Prepared for the State Water Resources Control Board, Sacramento, CA. 145 pages plus Appendices.

Sartory, D.P., and J.U. Grobbelaar. 1984. Extraction of chlorophyll-a from freshwater phytoplankton for spectrophotometric analysis. Hydrobiologia. 114:177-187.

Section A5: U.S. Geological Survey sediment monitoring and analysis

The following material was provided by David Schoellhamer and others specifically for this report. The submitted analyses are appended. Only the major points related to the predictions were excerpted for the body of the report. Because the report had figures embedded in the text and the report consists largely of extensive figure captions, we maintain that structure but add appropriate figure numbers.

Preliminary analysis of suspended-sediment concentration and turbidity in the fall low salinity zone of the San Francisco Estuary

David H. Schoellhamer, Tara L. Morgan-King, Maureen A. Downing-Kunz, Scott A. Wright, and Gregory G. Shellenbarger

Highlights

- X2 does not affect Fall suspended-sediment concentration at Mallard Island
- Fall suspended-sediment concentration at Mallard Island decreased by about one-half from 1994 to 2011
- Suisun Bay was usually more turbid than the confluence in Fall 1994-2011
- Suisun Bay was usually more turbid than the Cache Slough complex in Fall 2011
- Turbidity at Mallard Island was greater in Fall 2011 than 2010 but in the Cache Slough complex the opposite was observed with turbidity being greater in Fall 2010 than 2011.

Does X2 position affect suspended-sediment concentration?

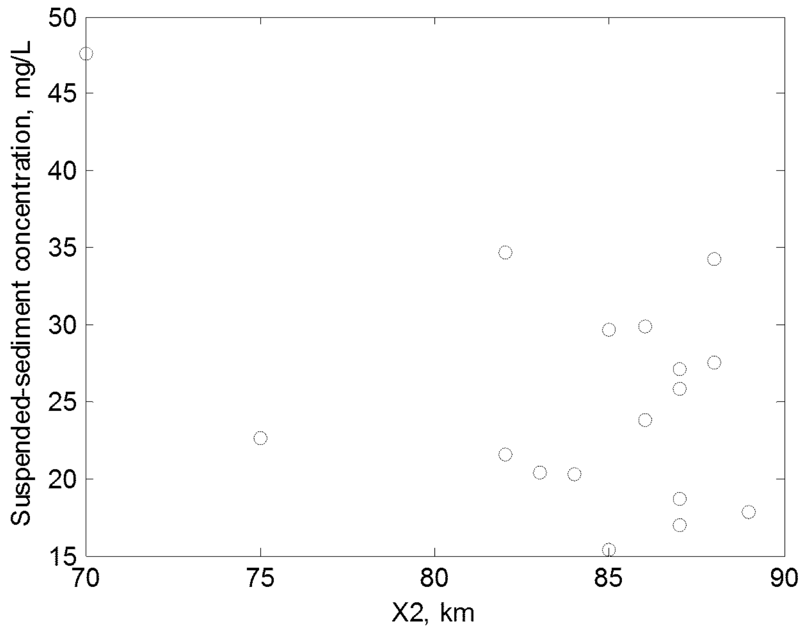

Figure A6. Near-surface suspended-sediment concentration (SSC) at Mallard Island as a function of X2, September-October mean values, 1994-2011. SSC data are collected at a 15-minute interval 1 meter below the water surface (Buchanan and Morgan 2011). 1995 is not included due to insufficient

SSC data. X2 does not appear to affect SSC.

Buchanan, P.A., and Morgan, T.L., 2011, Summary of suspended-sediment concentration data, San Francisco Bay, California, water year 2008: U.S. Geological Survey Data Series Report 634. http://pubs.usgs.gov/ds/634/

Did sudden clearing beginning in water year 1999 alter suspended-sediment transport processes?

Figure A7. Near-surface suspended-sediment concentration at Mallard Island, September-October mean values, 1994-2011. 1995 is not included due to insufficient SSC data. September-October SSC decreased about 50% from 1994-2011. Total suspended-solids concentration (equivalent to SSC in this estuary) in the Delta decreased 50% from 1975-1995 (Jassby et al. 2002). In 1999 there was a 36% step decrease in SSC in San Francisco Bay as the threshold from transport to supply regulation was crossed as an anthropogenic erodible sediment pool was depleted (Schoellhamer 2011). Thus, the decrease shown at Mallard Island is consistent with other observations in the estuary. Diminished supply from hydraulic mining debris, reservoirs, flood bypasses, and armoring of river banks are all likely contributors to the decrease.

Jassby, A.D., J.E. Cloern, and B.E. Cole. 2002. Annual primary production: Patterns and mechanisms of change in a nutrient-rich tidal ecosystem. Limnology and Oceanography 47: 698–712.

Schoellhamer, D.H., 2011, Sudden clearing of estuarine waters upon crossing the threshold from transport- to supply-regulation of sediment transport as an erodible sediment pool is depleted: San Francisco Bay, 1999: Estuaries and Coasts, v. 34, p. 885–899.

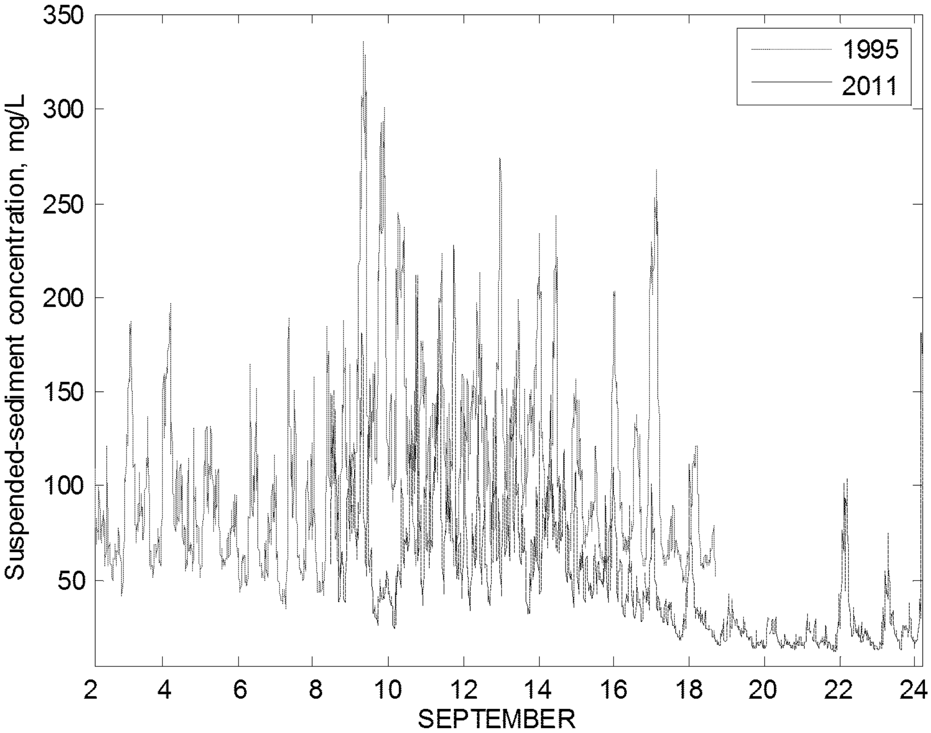

Figure A8. Suspended-sediment concentration (SSC) in Grizzly Bay at site GS, September 1995 and 2011. Data were collected 2.0 feet above the bottom in 1995 and 1.75 feet above the bottom in 2011. The period for which data have overlapping calendar dates is 10.2 days. For the dates with data in both 1995 and 2011, the following table provides a statistical summary of SSC in mg/L. For these data, mean SSC in 2011 was 45% less than in 1995. SSC decreases with distance from the bed and 2011 data were collected 0.25 feet closer to the bed than in 1995 which may lead to a small underestimation of the 1995-2011 decrease.

	1995	2011
mean	121	66
median	112	60
lower quartile	78	41
upper quartile	146	83

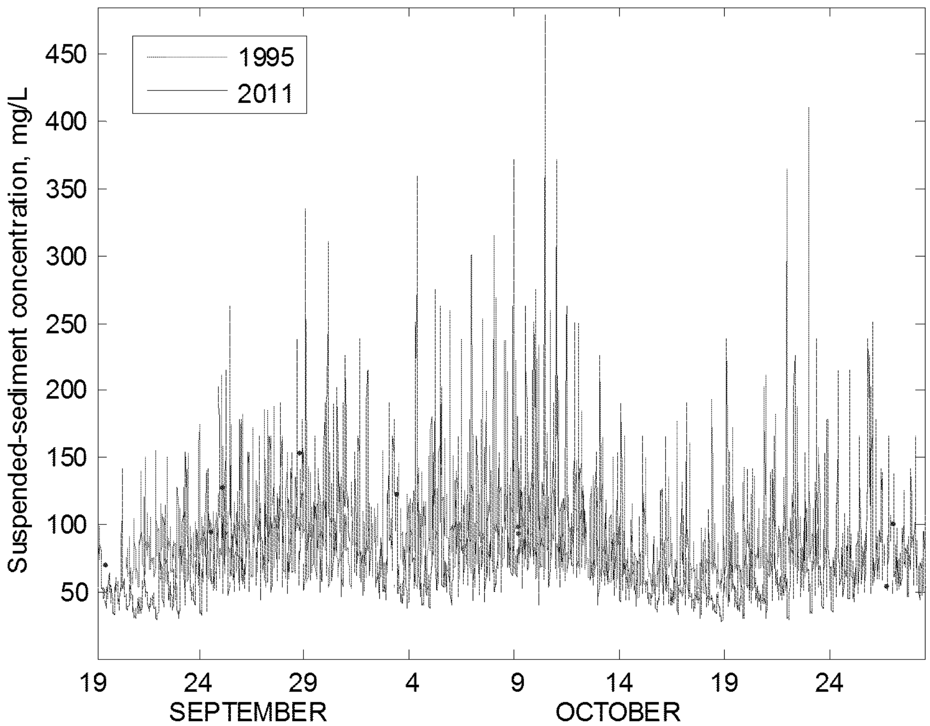

Figure A9. Suspended-sediment concentration (SSC) near the bottom in Suisun Cutoff, September-October 1995 and 2011. Data were collected 4 feet above the bottom in 1995 and 2.5 feet above the bottom in 2011. The period for which data have overlapping calendar dates is 33 days. For the dates with data in both 1995 and 2011, the following table provides a statistical summary of SSC in mg/L.

For these data, mean SSC in 2011 was 9% less than in 1995. The lower quartile decreased the most (25%) and the upper quartile decreased the least (4%). Brennan et al. (2002) found that tidal asymmetry in Suisun Cutoff caused greater SSC during flood tide. The highs are still high – perhaps because the tidal asymmetry mechanism is still present, and the lows are lower – perhaps because clearer water from elsewhere (SSC in Grizzly Bay and at Mallard Island have decreased almost one-half from the mid-1990s to 2011) is transported into Suisun Cutoff. SSC decreases with distance from the bed and 2011 data were collected 1.5 feet closer to the bed than in 1995 which may account for some of the smaller observed SSC decrease from 1990s-2011 than observed elsewhere.

	1995	**2011**
mean	89	81
median	85	71
lower quartile	69	52
upper quartile	101	97

Brennan, M.L., Schoellhamer, D.H., Burau, J.R., and Monismith, S.G., 2002, Tidal asymmetry and variability of bed shear stress and sediment bed flux at a site in San Francisco Bay, USA, in Winterwerp, J.C. and Kranenburg, C., ed., Fine Sediment Dynamics in the Marine Environment: Elsevier Science B.V., p. 93-108.

Is the confluence or Suisun Bay more turbid?

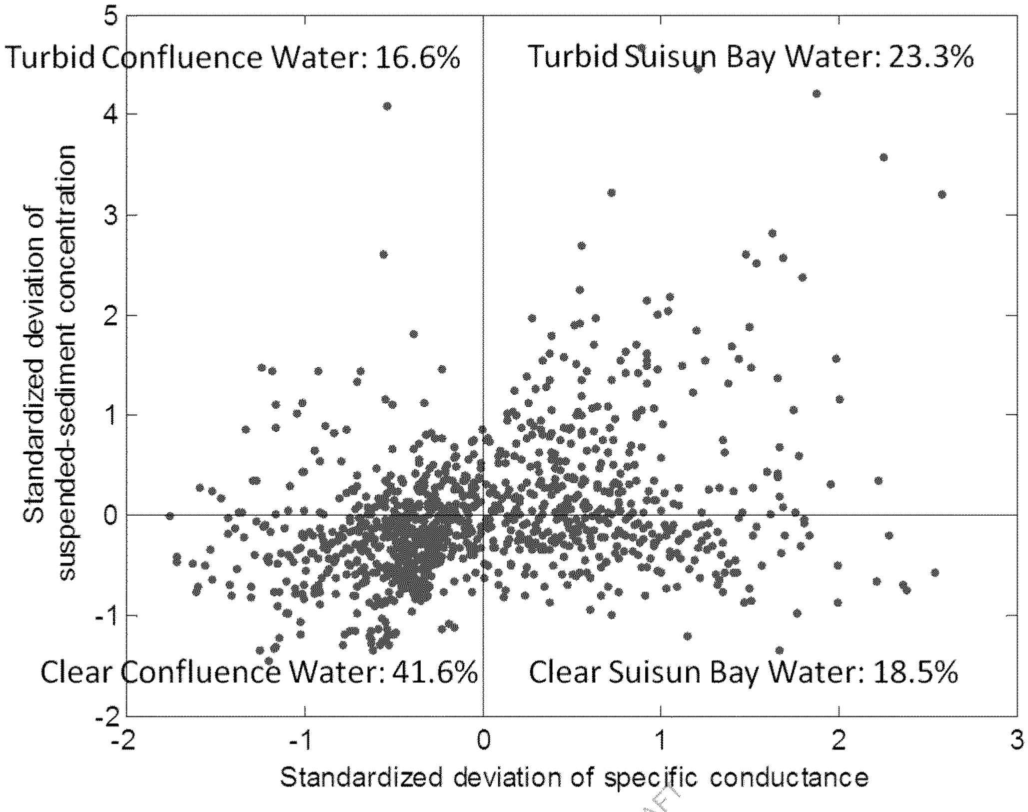

Figure A10. Standardized deviations of hourly specific conductance and suspended-sediment concentration from tidally-averaged values, Mallard Island, near-surface, September-October 2011. Positive deviation of specific conductance indicates water from seaward of Mallard Island (Suisun Bay) and negative deviation indicates water from landward of Mallard Island (confluence). Tidally-averaged time series were calculated with singular spectrum analysis for time series with missing data and a 40-hour window (Schoellhamer 2001). The modes with the greatest variability (40.1% for specific conductance and 47.6% for SSC) contained periodicity greater than 40 hours. All other significant modes contained tidal signals, so the first modes are tidally-averaged time series. The second and third modes were semidiurnal modes (37.2% of variability for specific conductance, 12.4% for SSC), indicating that advection was the most important tidal process. For SSC, quarter diurnal modes which are indicative of tidal resuspension accounted for only 7.4% of the variability. 64.9% of the data fell in the upper right or lower left quadrants, indicating relatively turbid water from Suisun Bay or relatively clear water from the confluence present at Mallard Island. Thus, Suisun Bay usually was more turbid than the confluence. This analysis assumes that advection is the dominant sediment transport mechanism.

Schoellhamer, D.H., 2001, Singular spectrum analysis for time series with missing data: Geophysical Research Letters, v. 28, no. 16, p. 3187-3190. URL http://ca.water.usgs.gov/ja/grl/ssam.pdf

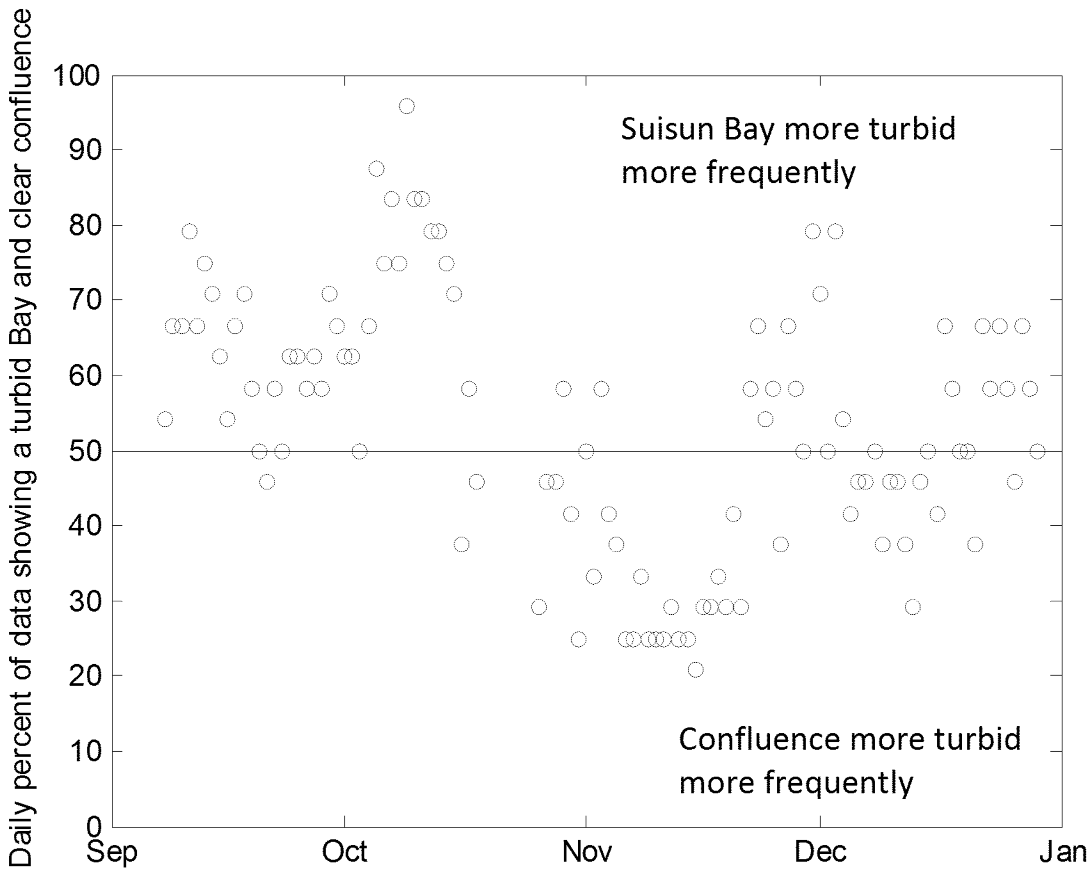

Figure A11. Percent of data showing a turbid Bay and clear confluence, September-December 2011. This was calculated from the product of hourly deviations of specific conductance and suspended-sediment concentration from tidally-averaged values. Positive values indicate instantaneous salinity and SSC are either both positive (relatively turbid Bay water) or negative (relatively clear confluence water). Negative values indicate that deviations of specific conductance and SSC have opposite signs (relatively clear Bay or relatively turbid confluence). Hourly data from Mallard Island are binned to compute daily values. This analysis assumes that advection is the dominant sediment transport mechanism. The magnitude of the deviations is not considered. The relative turbidity of Suisun Bay and the confluence varies with time. Several factors may affect this percentage, including wind-wave resuspension, the salinity field, river discharge, and the spring/neap tidal cycle.

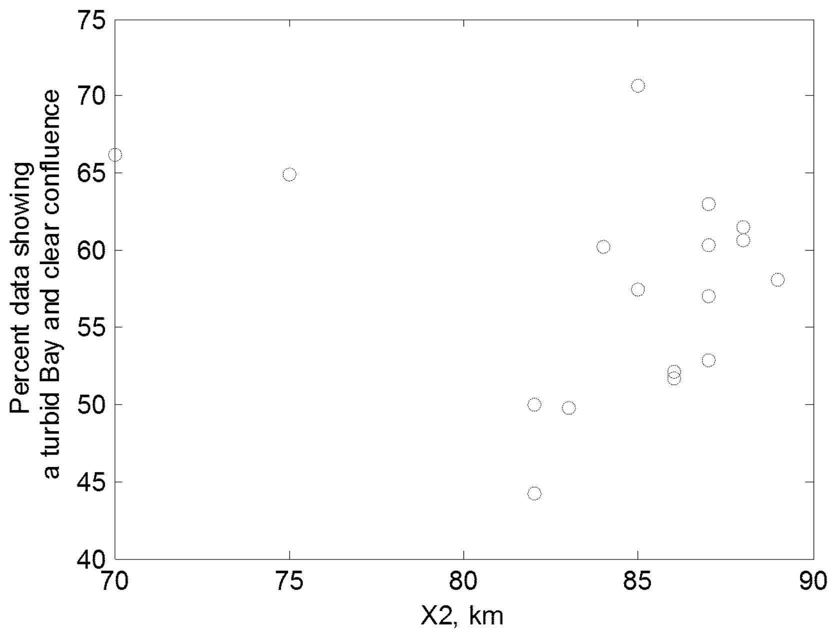

Figure A12. Percentage of specific conductance and SSC data from Mallard Island within the quadrants showing turbid waters to the west of Mallard Island (Suisun Bay) and clear waters to the east (confluence) as a function of X2, September and October, 1994-2011. 1995 is not included due to insufficient SSC data. X2 is the mean for September and October. Using daily X2 weighted by the fraction of good specific conductance and SSC data is virtually the same. In general, 50-65% of the data indicate Suisun Bay is more turbid and this percentage is independent of X2.

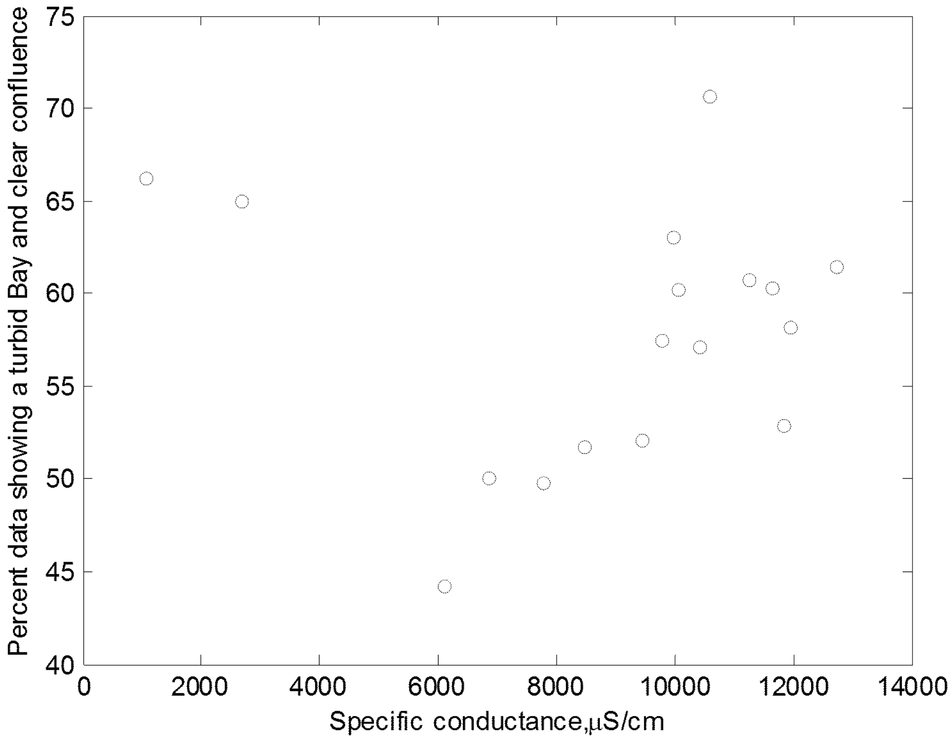

Figure A13. Percentage of specific conductance and SSC data from Mallard Island within the quadrants showing turbid waters to the west of Mallard Island (Suisun Bay) and clear waters to the east (confluence) as a function of mean specific conductance, September -October, 1994-2011. 1995 is not included due to insufficient SSC data. Only specific conductance measurements concurrent with valid SSC measurements are considered. In general, 50-65% of the data indicate Suisun Bay is more turbid and this percentage is independent of specific conductance. A possible decrease in the percentage at 6000-9000 μS/cm may be due to formation of a small estuarine turbidity maximum (ETM) landward of Mallard Island during neap tides around salinity of 0-2 (0-4000 μS/cm) (Schoellhamer 2001). An ETM landward of Mallard Island on neap tides would decrease the percentage (which is the mean over two months). For specific conductance less than 4000 μS/cm at Mallard Island the ETM would be centered at or seaward of Mallard Island. For specific conductance greater than 9000 μS/cm the ETM would be landward of Mallard possibly far enough that it would not be transported to Mallard Island on an ebb tide and thus the percentage remains high.

Schoellhamer, D.H., 2001, Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay, in McAnally, W.H. and Mehta, A.J., ed., Coastal and Estuarine Fine Sediment Transport Processes: Elsevier Science B.V., p. 343-357. URL: http://ca.water.usgs.gov/abstract/sfbay/elsevier0102.pdf

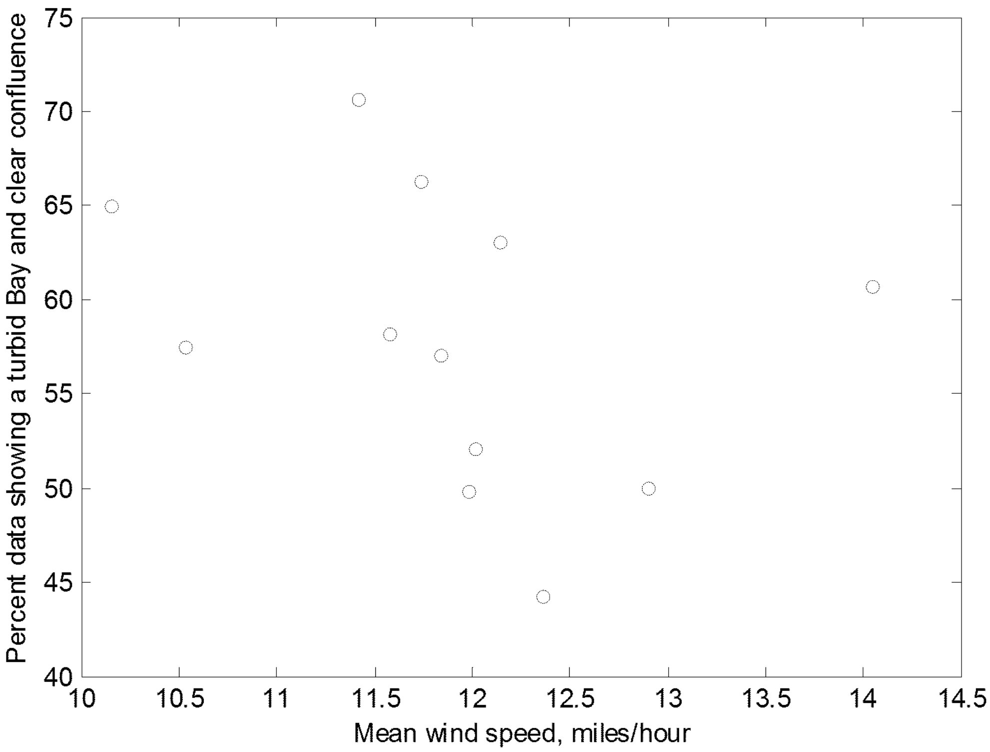

Figure A14. Percentage of specific conductance and SSC data from Mallard Island within the quadrants showing turbid waters to the west of Mallard Island (Suisun Bay) and clear waters to the east (confluence) as a function of mean wind speed, September -October, 1994-2011. 1995 is not included due to insufficient SSC data. Wind speed was measured hourly at Travis Air Force Base. No wind speed data are available

2000-2004. Only wind speed measurements concurrent with valid SSC and specific conductance measurements are considered. In general, 50-65% of the data indicate Suisun Bay is more turbid and this percentage is independent of wind speed. Note that the range of mean wind speed is only 4 mph, which may be insufficient to observe a relation. A preliminary hypothesis is that wind in September and October is usually capable of generating waves that resuspend sediment in Suisun Bay. This makes it more turbid than the confluence, except when a neap tide ETM is landward of Mallard Island and within a tidal excursion.

Is Suisun Bay or the Cache Slough/Liberty Island complex more turbid?

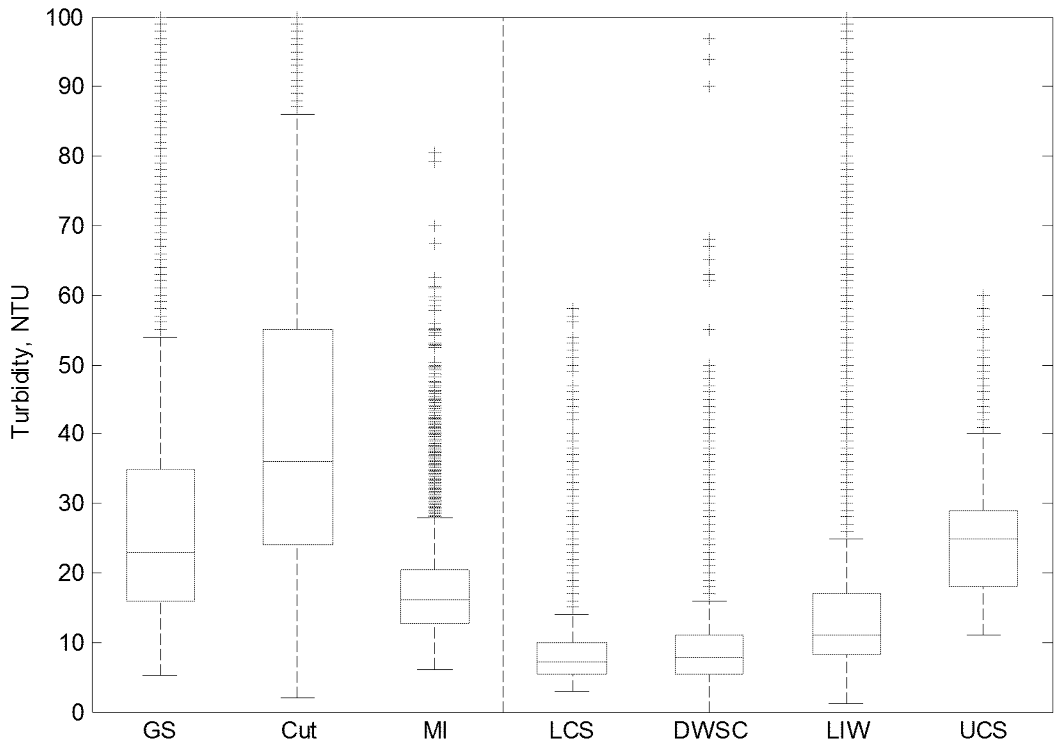

Figure A15. Boxplot of turbidity in Suisun Bay and the Cache Slough/ Liberty Island complex, September-

December 2011. Data were collected every 15 minutes and only times for which all 7 sites had valid data are considered (8257 times). The red horizontal line in each box is the median, the upper and lower ends of the boxes are the upper and lower quartiles, and the whisker length is the interquartile range or distance to the extreme value, whichever is less. Values beyond the whiskers are shown with an addition sign (+). Data points with turbidity greater than 100 NTU are not shown. Suisun Bay sites are Grizzly Bay shallows (GS), Suisun Cutoff near-bottom (Cut), and Mallard Island near-surface (MI). Mallard Island turbidity data are from CDEC (http://cdec.water.ca.gov/). USGS measured turbidity at all the other sites. The vertical dashed line separates Suisun Bay and Cache Slough complex sites. Cache Slough complex sites are Lower Cache Slough mid-depth (LCS), Deep Water Ship Channel adjacent shallows (DWSC), Liberty Island shallows (LIW), and Upper Cache Slough near-bottom (UCS). Suspended-sediment concentration and therefore turbidity increase with water depth at a given site, so sensor position in the water column must be considered when analyzing these results. For shallow sites, Grizzly Bay was more turbid than Liberty Island and DWSC. For near-bottom sites, Suisun Cutoff was more turbid than Upper Cache Slough. And for near-surface and mid-depth sites, Mallard Island was more turbid than Lower Cache Slough. For all these comparisons, Suisun Bay sites were more turbid than Cache Slough complex sites.

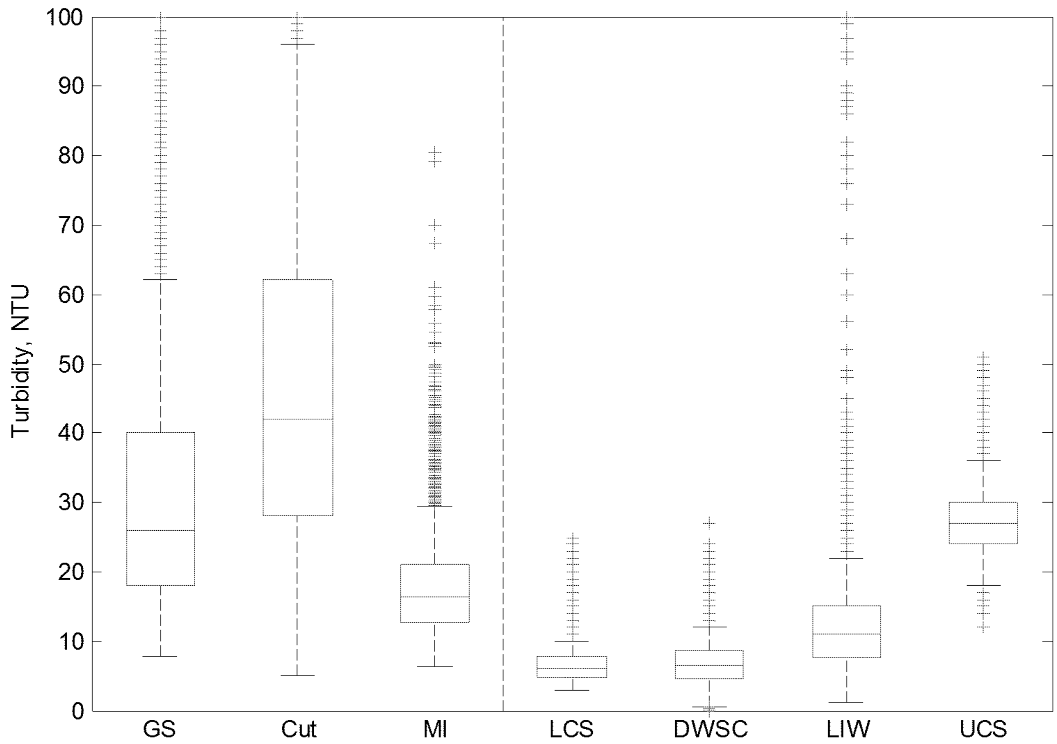

Figure A16. Boxplot of turbidity in Suisun Bay and the Cache Slough/ Liberty Island complex, September-October 2011. This figure is a subset of the previous figure. Data were collected every 15 minutes and only times for which all 7 sites had valid data are considered (4557 times). The red horizontal line in each box is the median, the upper and lower ends of the boxes are the upper and lower quartiles, and the whisker length is the interquartile range or distance to the extreme value, whichever is less. Values beyond the whiskers are shown with an addition sign (+). Data points with turbidity greater than 100 NTU are not shown. Suisun Bay sites are Grizzly Bay shallows (GS), Suisun Cutoff near-bottom (Cut), and Mallard Island near-surface (MI). Mallard Island turbidity data are from CDEC (http://cdec.water.ca.gov/). USGS measured turbidity at all the other sites. The vertical dashed line separates Suisun Bay and Cache Slough complex sites. Cache Slough complex sites are Lower Cache Slough mid-depth (LCS), Deep Water Ship Channel adjacent shallows (DWSC), Liberty Island shallows (LIW), and Upper Cache Slough near-bottom (UCS). Suspended-sediment concentration and therefore turbidity increase with water depth at a given site, so sensor position in the water column must be considered when analyzing these results. For shallow sites, Grizzly Bay was more turbid than Liberty Island and DWSC. For near-bottom sites, Suisun Cutoff was more turbid than Upper Cache Slough. And for near-surface and mid-depth sites, Mallard Island was more turbid than Lower Cache Slough. For all these comparisons, Suisun Bay sites were more turbid than Cache Slough complex sites.

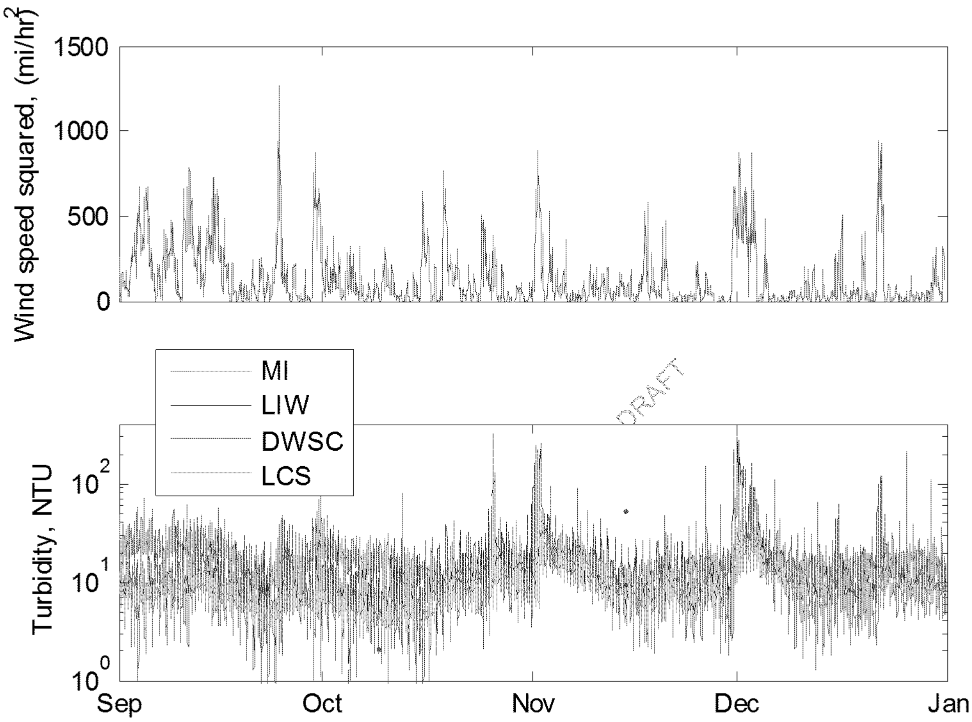

Figure A17. Wind speed squared and turbidity, September – December 2011. Wind speed was measured at Travis Air Force Base. Wind shear stress on the water surface is roughly proportional to the square of the wind speed. Turbidity is shown at four sites: Mallard Island (MI), Liberty Island shallows (LIW), Deep water ship channel (DWSC), and Lower Cache Slough (LCS). Note that a logarithmic scale is used for turbidity. Turbidity at Mallard Island (blue line) is usually greater than in the Cache Slough complex except during some windy events when wind-wave resuspension in Liberty Island (green line) increases turbidity in Deep Water Ship Channel and Lower Cache Slough. Wind direction is not considered in this initial analysis.

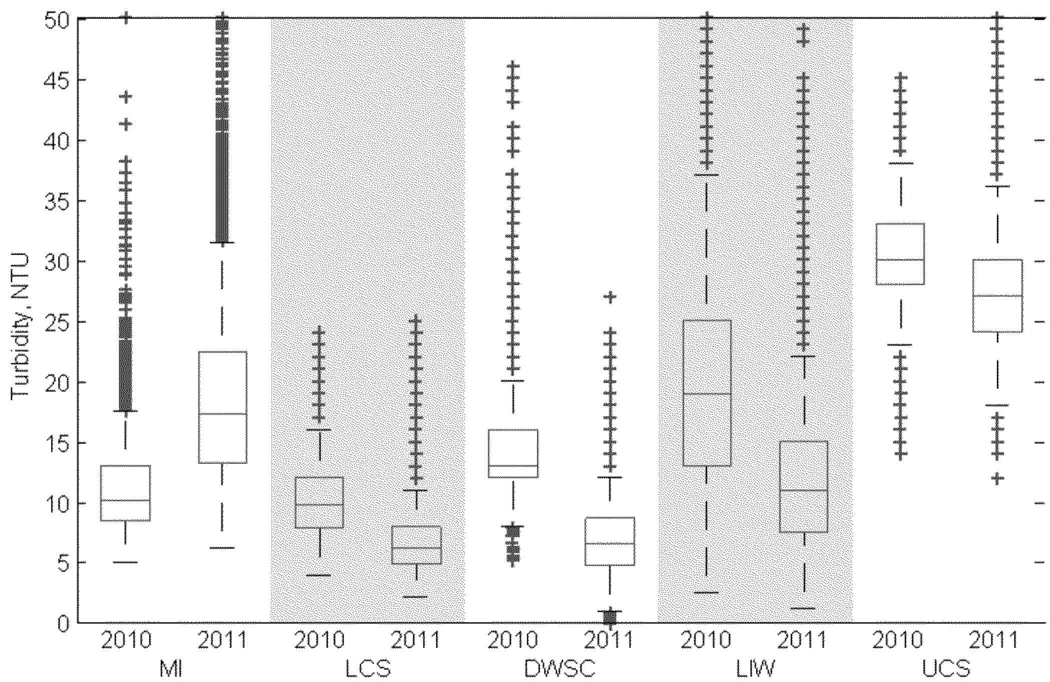

Figure A18. Boxplot of turbidity at Mallard Island and the Cache Slough/ Liberty Island complex, September-October 2010 and 2011. Data were collected every 15 minutes and only times for which all 5 sites in a given water year had valid data are considered (2418 for 2010 and 5452 for 2011). The red horizontal line in each box is the median, the upper and lower ends of the boxes are the upper and lower quartiles, and the whisker length is the interquartile range or distance to the extreme value, whichever is less. Values beyond the whiskers are shown with an addition sign (+). Data points with turbidity greater than 50 NTU are not shown. Mallard Island (MI) turbidity data are from CDEC (http://cdec.water.ca.gov/) and were edited to remove sensor drift likely caused by biofouling. USGS measured turbidity at all the other sites. Cache Slough complex sites are Lower Cache Slough mid-depth (LCS), Deep Water Ship Channel adjacent shallows (DWSC), Liberty Island shallows (LIW), and Upper Cache Slough near-bottom (UCS). Gray shading is used to delineate sites. Suspended-sediment concentration and therefore turbidity increase with water depth at a given site, so sensor position in the water column must be considered when analyzing these results. Mallard Island was more turbid in 2011 than 2010 and Cache Slough complex sites were the opposite with 2010 being more turbid than 2011. In 2010, Mallard Island was about as turbid as LCS and less turbid than the remaining Cache Slough complex sites. In 2011, Mallard Island was more turbid than all Cache Slough complex sites except UCS. A hypothesis for the difference between 2010 and 2011 is that Yolo Bypass flow in 2011 reduced deposition in the Cache Slough complex and greater watershed sediment supply in 2011increased deposition in Suisun Bay and that this more seaward deposition in 2011 accounts for the observed turbidity. Another hypothesis is that in 2010 the estuarine turbidity maximum at 0-2 psu (Schoellhamer 2001) was landward of Mallard Island at all times while it was often present at Mallard Island in 2011, leading to greater turbidity in 2011.

Schoellhamer, D.H., 2001, Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay, in McAnally, W.H. and Mehta, A.J., ed., Coastal and Estuarine Fine Sediment Transport Processes: Elsevier Science B.V., p. 343-357. URL: http://ca.water.usgs.gov/abstract/sfbay/elsevier0102.pdf

Section A6: Environmental Monitoring Program

The Environmental Monitoring Program of the IEP is carried out cooperatively by several IEP agencies. Sampling is conducted monthly. The following information is excerpted from the following web site: *http://www.water.ca.gov/iep/activities/emp.cfm*. Additional information on zooplankton sampling can be obtained at: *http://www.water.ca.gov/bdma/meta/zooplankton.cfm*

The Environmental Monitoring Program (EMP) for the Sacramento-San Joaquin

Delta, Suisun Bay, and San Pablo Bay is conducted under the auspices of the Interagency Ecological Program (IEP). The EMP was initiated in 1971 in compliance with California State Water Resources Control Board (SWRCB) Water Right Decision D-1379 and continued from 1978 through 1999 under D-1485. Currently it is mandated by Water Right Decision D-1641. The program is carried out jointly by the two water right permittees operating the California water projects, the United States Bureau of Reclamation (USBR) and the California Department of Water Resources (DWR). Assistance is provided by the California Department of Fish and Game (CDFG) and the United States Geological Survey (USGS). The primary purpose of the IEP EMP is to provide necessary information for compliance with flow-related water quality standards specified in the water right permits. In addition, the EMP also provides information on a wide range of chemical, physical and biological baseline variables. EMP's discrete water quality stations are sampled monthly using a research vessel and a laboratory van. EMP also operates eight multi-parameter continuous "real-time" water quality stations. In addition, the EMP collects and analyzes benthos, phytoplankton, and zooplankton samples. Monitoring listed as "continuous recorder sites" in D-1641 is not part of the EMP, these sites are operated by the USBR, the USGS or DWR.

We use data from 6 fixed sites in the EMP sampling network (Fig. A19). We also include data from 2 "floating" sites, EZ2 and EZ6. These samples are taken at locations where near bottom specific conductance are 2,000 and 6,000 μS/cm, respectively. We use data for ammonium, nitrite + nitrate, chlorophyll-a, and zooplankton. Water quality data were determined from samples collected 1 m below the surface. All data used in this report will be posted to an accessible website/ftp site once analyses are finalized in response to review panel comments.

Figure A19. Sites sampled by the IEP Environmental Monitoring Program (EMP) for water quality constituents are shown by circles. Red circles show the sites considered representative of delta smelt fall range. Black circles show sites considered outside of the fall range of delta smelt and not included in analyses.

Section A6: U.S. Geological Survey Water Quality Monitoring

The USGS maintains a comprehensive database documenting the methods used and results from long term monitoring of the San Francisco estuary (*http://sfbay.wr.usgs.gov/access/wqdata/index.html*). Sampling is conducted monthly. We utilize data from samples collected 2 m below the surface. We use data for ammonium, nitrite + nitrate, and chlorophyll-*a*. Ammonium and nitrite + nitrate are presented in terms of micromoles in the USGS database. For purposes of comparison we converted these concentrations to mg/L. Because separate concentrations of nitrite and nitrate were not available the conversion was made assuming 100% nitrate in the samples. This could bias the data slightly high. We used data from 7 sites (Fig. A20), where discrete water samples were taken for analysis. Data from site 5 were used when data from site 6 were not available. These sites were considered to be representative of water quality in the fall range of delta smelt.

Figure A20. Sites sampled by the USGS water quality monitoring program (http://sfbay.wr.usgs.gov/access/wqdata/index.html) for water quality constituents. Data utilized for this report are from sites indicated by arrows where discrete water samples were collected.